FY 2009 Annual Report
National Program 206—Manure and Byproduct Utilization

Introduction

According to the National Agricultural Statistics Service, over one billion tons of agricultural (e.g., manure), municipal (e.g. biosolids), and industrial (e.g. coal combustion products) wastes with potential uses in agriculture are generated annually in the United States. Many of these materials are spread, sprayed or otherwise applied to agricultural land because of the benefits they provide. These benefits include: providing a nutrient source for crops; improving soil chemical, physical and biological properties; improving soil water storage and use; reducing movement of contaminants to water and air; and reducing production costs and energy use. However, improperly managed manure and other byproducts can pose a threat to soil, water and air quality, and to human and animal health.

The goal of the Agricultural and Industrial Byproducts National Program is to develop and evaluate management practices and systems, control technologies, and decision tools to allow producers and their advisors to (1) use manure and other byproducts effectively and safely while protecting the environment and human and animal health and (2) provide policy-makers and regulators with information and tools to establish appropriate conservation and environmental credit trading programs, and make environmental protection decisions. To achieve this goal, this National Program is focused on four major areas of research: atmospheric emissions, nutrient management, pathogens and pharmaceutically active compounds, and municipal and industrial byproducts. Sustainable agriculture depends on effective management of manure and byproducts. Selected accomplishments from these four components are described in the following section.

Atmospheric Emissions: Air emissions from animal production operations and land application of manure and other byproducts include particulate matter, ammonia, volatile organic compounds (that cause odor or serve as precursors for ozone formation), hydrogen sulfide, greenhouse gases and pathogens. Research is being conducted to: (1) develop new methods and improve existing methods to measure particulate matter and gaseous emissions; (2) develop and determine the effectiveness and environmental benefits of management practices and control technologies to reduce emissions; and (3) develop and test decision tools to predict emissions and their dispersion across a range of animal production systems, management practices, and environmental conditions. Tools and practices for measurement, control and prediction of emissions from animal production operations will help provide the scientific background for management, policy and regulatory decisions.

Selected Accomplishments

Development of a green and profitable manure treatment technology. New or expanding swine production facilities in North Carolina are required to use manure management systems that meet the strictest environmental performance standards in the nation. A second-generation system was developed by ARS-Florence scientists and cooperators that met state environmental standards for manure management. The new on-farm treatment system uses solid-liquid separation and nitrogen and phosphorus removal processes (U.S. Patent Application US 2008/0314837) to remove high levels of several pollutants from manure wastewater, including almost all of the pathogens, odor-causing constituents, and ammonia. Replacing anaerobic-lagoon-based systems with this new technology reduced greenhouse gas emissions by 97 percent. Animal health and production also benefited. Swine daily weight gain increased, feed conversion improved, animal mortality decreased, and 5.6 percent more hogs were sold per growing cycle. In a centralized facility, separated manure solids were converted to composted materials and used for organic plant fertilizer, soil amendments, and plant growth media. Through these innovations and on-farm testing, significant cost reductions were achieved. This revamped system was two-thirds less expensive to build and operate than the first-generation system (tested in 2003). Producers can also profit from this new system by selling both greenhouse gas emission reduction and water quality credits.

Fate of odorants from animal feeding operations is as important as emission rates. The National Research Council has identified odors as the most significant animal emission problem at the local level. In a large collaborative study with ARS-Ames, Kansas State University, and ARS-Beltsville, the concentrations of odorant compounds were determined at several distances from a large cattle feedlot in Kansas. Results showed that volatile fatty acids (VFAs), indole (a nitrogen aromatic compound), and phenols were most prevalent at the feedlot, but that VFAs were much less important two miles from the lot. This suggests that mitigation strategies that only focus on controlling the rate of emissions from farms will not necessarily solve downwind nuisance odor problems. The fate of each chemical once it is released into the atmosphere must be considered and the detection threshold of each chemical relative to its concentration are both needed to prioritize odor reduction efforts and to evaluate the effectiveness of best management practices.

Remediating Odor from Livestock Waste. Malodors from confined animal feeding operations are a source of complaints and may have adverse environmental impacts. ARS Scientists from Bowling Green, KY, and Florence, SC, studied reductions in malodor effected by a second generation wastewater treatment plant during three cycles of pig rearing. The wastewater treatment system consisted of three modules: solids separation, biological nitrogen removal, and phosphorus recovery/wastewater disinfection. While approximately 90% of the wastewater solids were removed in the first stage of treatment, little reduction in malodorous compounds occurred, indicating that malodorous compounds largely remained with the liquid waste stream. The greatest improvements in wastewater quality occurred in the nitrogen treatment module, where malodorous compounds were reduced by more than 90% as compared to the raw flushed

manure. The system consistently achieved high performance standards, even during the first cycle of livestock production when system performance was being optimized. Combining two simple processes into a practical treatment system can be very effective in reducing malodorous compounds from livestock wastewater.

Field assessment of Nitrous Oxide (N2O) emissions from manure applied to soil. Nitrous oxide (N_2O) is a greenhouse gas that is many times more potent than carbon dioxide in terms of global warming potential. Agriculture is the largest human-related source of nitrous oxide emissions. ARS scientists studied the temporal patterns of N_2O emissions following addition of swine manure slurry under fluctuating soil moisture regimes, assessed the potential of a rye cover crop to decrease N_2O emissions under these conditions, and quantified field N_2O emissions in response to either spring applied conventional nitrogen fertilizer or different rates of fall-applied liquid swine manure, in the presence or absence of a rye/oat winter cover crop. Results showed a significant reduction in N_2O emissions in the presence of the rye cover crop. Nitrous oxide emissions were evaluated at three swine manure application rates and with spring applied fertilizer, in the presence or absence of an oat/rye cover crop. The primary factor influencing N_2O emission was nitrogen (N) application rate, regardless of form or timing. The response of N_2O emission to N additions was non-linear, with an increasing proportion of the applied nitrogen being emitted as N_2O as total N application rates were increased. These results indicate that while cover crops have the potential to reduce N_2O emissions, N application rate may be the overriding factor, thus emphasizing the need for careful N application management practices.

Ammonia Emissions from Beef Cattle Feedyards. A recent ruling by the Environmental Protection Agency (EPA) required cattle feeders to report ammonia emissions under the Emergency Planning and Community Right-to-Know Act (EPCRA). At the request of the Texas Cattle Feeders Association, ARS researchers at the Conservation and Production Research Laboratory, Bushland, Texas, led a group of scientists from ARS and Texas AgriLife Research that compiled the state-of-the-science of ammonia emissions from cattle feedyards. This report was used by the National Cattlemen's Beef Association (NCBA) to develop a worksheet used to estimate feedlot ammonia emissions that could be used to meet EPCRA reporting requirements. The worksheet was delivered online, in newsletters and through an online webinar to NCBA affiliates, which reached about 85% of the cattle feeding industry and allowed the cattle industry to meet the regulatory reporting requirements, despite a very short deadline.

Developing Emission Factors for Open-lot Dairies in Southern Idaho. In Idaho, the number of dairy cows has increased by approximately 88% in the last decade with concentrated dairy production facilities being the norm, generating environmental concerns related to regional air quality. Ammonia, methane, carbon dioxide, and nitrous oxide emissions were determined on a 10,000 milking cow open-lot dairy in southern Idaho. This work was performed by ARS scientists at the Northwest Irrigation and Soils Research Laboratory (NWISRL), Kimberly, Idaho. Emissions were determined for several days each month over the course of a year at three locations: the cattle pens, lagoon, and compost areas. This study reports some of the first ammonia, methane,

carbon dioxide and nitrous oxide emissions data from a large scale open lot dairy production facility that encompasses both daily and seasonal variations in emissions and will provide preliminary data for the development of emissions factors from this type of production facility. Emissions factors will be used to estimate atmospheric emissions from producers operations for proposed EPA permit/regulatory purposes.

Nutrient Management: The utilization of nutrients in manure in an environmentally sustainable manner is one of the critical management issues facing livestock producers. Movement of nutrients in excess amounts from manure and other byproducts to soil, water and air can cause significant environmental problems. Nitrogen and phosphorus from manure and other sources have been associated with algal blooms, accelerated eutrophication of lakes and streams, and development of hypoxic zones in the Gulf of Mexico. ARS scientists are conducting research to develop management practices, control technologies, and decision tools for effective agricultural use of nutrients from manure and other byproducts, while protecting environmental quality and public health.

Selected Accomplishments

Poultry Litter is Superior to Commercial Fertilizers for Cotton. Increasing conventional fertilizer costs and the local availability of poultry litter pose questions about the potential value of poultry litter as a fertilizer source for cotton producers. ARS Genetics and Precision Agriculture Research scientists at Mississippi State, MS, found poultry litter to be superior to conventional inorganic fertilizers in certain marginally productive upland soils. On soils that historically have low productivity, cotton fertilized with raw litter produced up to 26% more lint than cotton fertilized with conventional inorganic fertilizers. In soils that are considered more productive, poultry litter and conventional fertilizers had comparable effects on cotton lint production. Thus poultry litter has the potential to replace many of the commonly used and more expensive cotton fertilizers in all soils, increasing the profitability of cotton production in the southern and southeastern states.

Benefits of Shallow Subsurface Band Application of Poultry Litter. Poultry litter is typically land-applied by broadcast surface application, but this method has a high potential for undesirable transport of litter nutrients off the field into streams, rivers, lakes, and other bodies of water. An experimental four-trench litter applicator field implement that applies litter in shallow subsurface bands in soil was used in five field experiments. When the poultry litter was applied in subsurface bands, phosphorus and nitrogen concentrations in water running off field plots were reduced by 80 to 95% compared to traditional broadcast surface application. Use of the implement by producers and others who apply litter to fields is expected to reduce pollution of streams, rivers, lakes, and other bodies of water, while maximizing the nutrient value of the litter to farmers.

Management recommendations for temporary storage of poultry litter. Temporary in-field storage piles of poultry litter are commonly used in the mid-Atlantic region due

to a shortage of on-farm litter storage and the desire to transport and disperse the litter to more distant areas which have not been heavily manured. A ten member technical expert panel of ARS, NIFA, and industry scientists reviewed the literature on temporary storage piles of litter and developed a set of recommendations for using this in-field storage technique. The findings and recommendations include: minimizing the need for using in-field storage by increasing on-farm storage, using an "A" shaped pile to minimize the pile footprint and runoff, locating piles on well-drained level land distant from surface waters with site location changed each year, allowing piles to remain intact until just before spreading because the greatest nutrient losses occur after land application, develop soil and agronomic practices for remediation of the stockpile footprint, and encouraging land application that includes shallow incorporation or injection. These recommended management practices will conserves nutrients for the producer and minimize nutrient losses to the Chesapeake Bay and elsewhere.

Diets Including Forages for Developing Replacement Heifers Require No Supplementation of Phosphorus. When phosphorus (P) is fed to cattle in amounts greater than they can utilize, the excess is excreted in the manure. If phosphorus-rich manure is later spread on farm fields to provide nutrients for growing crops, it can also cause an excess of phosphorus in runoff that promotes the growth of undesirable algae in receiving aquatic systems. Phosphorus is essential for bone growth and development in growing dairy heifers. The amount of dietary phosphorus needed in dairy heifer diets is very similar to that found naturally in many forages comprising typical heifer diets. Scientists from the University of Wisconsin-Madison and the U.S. Dairy Forage Research Center conducted a long-term trial on phosphorus supplementation with heifers ranging from 4 to 22 months of age. Heifers were fed diets with or without supplemental phosphorus resulting in dietary phosphorus concentrations of 0.29 or 0.39%. Results showed that phosphorus supplementation for developing replacement heifers had minimal effect on the extent of frame development, bone density, or bone metabolism. A parallel experiment evaluating runoff from simulated rain on applied manures from heifers showed that incorporating manure reduced P losses in runoff by 85-90%, and that manure from heifers fed unsupplemented diets resulted in lower P concentrations in runoff than those fed P-supplemented diets. This information will help dairy producers and nutritionists formulate heifer rations that contain adequate, but not excessive, amounts of phosphorus, so that the growth needs of the heifers are met without adding excess phosphorus to the environment.

An updated website at Cornell is improving whole-farm nitrogen management. Nitrogen management on Northeast dairy farms is a challenge because of the range of farm-grown feeds, the wide array of manure management systems, and the wide range of field crops and soils across the region. Cooperative research among several Northeast Land-grant Universities and ARS scientists in Beltsville has provided an on-line nitrogen management tool describing best management practices for dairy farms that utilizes a whole-farm perspective. The web site, http://www.dairyn.cornell.edu/, was updated and now contains components on concerns about nitrogen losses, crop and soil nitrogen management, feed storage nitrogen management, dairy herd nitrogen management including precision feeding, manure storage nitrogen management, and integrating the

above components into a whole-farm system. The web site has been written up in several popular press articles and is an important resource for Extension agents, dairy consultants, USDA-NRCS (Natural Resources Conservation Service) agents, and nutrient managers as they develop site-specific whole-farm nutrient management plans for Northeastern dairies.

Snap-shot Assessment of Nutrient Use Efficiency on Confinement Dairy Farms. Nutrient use efficiency can be broadly defined as the relative amount of feed, fertilizer and/or manure nutrients inputs that are incorporated into milk, crops/pasture or other outputs. Relatively little information is available on nutrient use efficiency on commercial dairy farms, or on how it can be measured and evaluated for impacts on profitability and environmental performance. Over the past several years, researchers at the U.S. Dairy Forage Research Center and the University of Wisconsin-Madison have developed tools that can be used to provide snap-shot assessments of feed, fertilizer, and manure use on dairy farms in various settings. A website was developed that contains (1) a Fact Sheet giving an overall explanation of nutrient use efficiency, the importance of knowing it, and how to measure it; (2) a Nutrient Management Survey questionnaire; (3) a Manure Spreading Book – a document to help dairy producers keep track of when, where, and why they spread manure; (4) an example of a Final Farmer Report; and (5) four scientific journal articles related to nutrient use efficiency on confinement dairy farms. Snap-shots tools and their results have been used (1) to develop recommendations about how to integrate dietary, livestock management, and manure handling practices into comprehensive nutrient management programs, and (2) to identify management practices that bring dairy farms into better nutrient balance while maintaining farm productivity and profitability. They have been adapted for use by (1) extension educators involved in nutrient use training, (2) decision-makers working to develop guidelines and regulations for improving nutrient management, and (3) university students, many of whom will be researchers, conservation program staff, or consultants assisting dairy farmers with nutrient management in the future.

Pathogens and Pharmaceutically Active Compounds: Pathogens and pharmaceutically active compounds in manure, biosolids, and other byproducts can be transmitted to animals and humans through food supplies, water and possibly air. Livestock and poultry can also be re-infected not only via water and air, but from other vectors such as birds, rodents and insects. The most significant of the manure-borne zoonotic pathogens are the protozoan parasites Cryptosporidium parvum and Giardia duodenalis, and the bacterial pathogens Salmonella, Campylobacter, Escherichia coli, and Listeria monocytogenes. Pharmaceutically active compounds such as hormones and antibiotics may also be present in animal waste and disseminated in the environment. The potential for serious health effects both on and off the farm, the lack of knowledge about pathogen survival in manure during collection, storage, treatment and application, and uncertainty about fate and transport of pathogens in soil, water and air from the animal production site or manure application area, clearly point to the need for research on these issues.

Selected Accomplishments

Determining the concentrations of hormones in biosolids and poultry litter. The presence of natural hormones and the synthetic hormone ethinylestradiol was monitored in lime-treated biosolids and poultry litter samples in order to determine the likely potential of these compounds to run off from fields treated with these materials as soil amendments. These hormones exist in their free form and as chemical conjugates requiring more sophisticated measurement techniques such as liquid chromography triple quadrupole mass spectrometry. Estrone, estrone sulfate, and progesterone were found most frequently, with the concentrations in biosolids typically less than 10 ng/g. Concentrations in poultry litter were somewhat higher. Estriol, estradiol, ethinylestradiol, and testosterone were seldom detected. This information can be used to design cost-effective treatments to reduce the concentrations of these compounds in land-applied biosolids and litter as well as more focused monitoring programs to insure that these compounds are not transported off site and into waterways.

Measurement of the environmental fate of hormones in poultry litter. Poultry litter contains the reproductive hormones estradiol and testosterone. These are endocrine disruptors that have been detected in surface waters worldwide. The objective of this study was to evaluate the potential impact of poultry litter applications on estradiol and testosterone concentrations in subsurface drainage and surface runoff in irrigated crop land under no-till and conventional-till management. The differences between no-till and conventional-tillage appeared to be related to variation in hydrologic transport for the two tillage systems. Although differences were observed between tillage practices, the application of poultry litter at rates set by the nutritional requirements of the crop appears to have little potential of contaminating surface and subsurface waters with these hormones. This is important information for the poultry industry and environmental protection agencies because surface waters contaminated with hormones from poultry litter are likely an indication of inappropriate or mismanagement of litter applications.

Determining the fate of antimicrobials in agricultural lands receiving biosolids. The antimicrobial pesticides, triclosan and triclocarbon, are often found in soap, detergents, and antiseptics, and have been found in biosolids from waste water treatment facilities. These compounds, which are highly toxic to aquatic organisms, are strongly sorbed to biosolids, but can be released to the environment when biosolids are applied to agricultural fields. Studies were conducted to determine the likely concentrations of triclosan and triclocarban in biosolids by examining their sorption to biosolids during treatment of waste water and then following their fate in land applied biosolids, a major (60%) disposal practice in the U.S. Concentrations in fresh biosolids averaged 16 and 18 mg/Kg, respectively for triclosan and triclocarbon; the half life of triclosan after biosolids application was more than 100 days, and many times longer for triclocarban. The persistence of these compounds means that more research on the factors controlling the release of these compounds from land-applied biosolids and their potential transport offsite is needed to minimize negative effects to surrounding ecosystems.

ARS participates in an interagency task force on pharmaceuticals in the environment. An interagency report, "Pharmaceuticals in the Environment: An Interagency Research Strategy" was completed with ARS as a work group member. This report was commissioned by the Committee on the Environment and Natural Resources, Office of Science and Technology Policy. The purpose of this report was to summarize federal research in this area and to develop an integrated interagency strategy for conducting investigations on priority research needs identified by the work group. The following outcomes from this planning document are being implemented: 1) coordinate animal feeding operation studies to examine the contribution of pharmaceuticals to the environment combined with exposures from waste water treatment plant discharges; 2) organize an analytical user's group; and 3) highlight the stewardship activities in USDA and coordinate USDA National Institute for Food and Agriculture (NIFA) granting efforts into the research plan.

Variations of fecal indicator bacteria in a large urban watershed. Data from the Santa Ana River watershed, Southern California, USA demonstrate that both existing and Environmental Protection Agency (EPA)-recommended water quality criteria for allowable bacteria levels are routinely exceeded in this watershed, often by one or more orders of magnitude. Total coliform (TC), fecal coliform (FC), E. coli, enterococci, and total bacterial concentrations were monitored by ARS scientists at Riverside, CA in 13 locations in the watershed over a two year period. Bacterial count estimates changed far more significantly across different sites, in comparison to seasonal flow estimates or estimates across time. These results imply that TC, FC, E. coli, and enterococci bacterial counts in the two tributaries are strongly influenced by spatial location, with contamination due to local agricultural and/or urban run-off as opposed to elevated up-stream contamination and/or discharge contamination associated with the two wastewater treatment plants (WWPT). Therefore, this study has provided useful information that can be used in constructing watershed management plans for a mixed use watershed.

Assessing the diversity in cell properties and transport behavior among 12 different environmental Escherichia coli isolates. Escherichia coli (E. coli) is a common fecal-borne pathogenic microorganism in water supplies. The importance of E. coli as an indicator organism has led to numerous studies looking at cell properties and transport behavior of this microorganism. In many of these studies, however, only a single strain of E. coli was used even though research has shown a significant amount of genetic variability exists among different strains of E. coli. If this genetic diversity results in differences in cell properties that affect transport, different strains of E. coli may exhibit different rates of transport in the environment. Research was conducted at the ARS Animal Waste Management Unit in Bowling Green, KY, in collaboration with the University of California – Riverside, to assess the variability in surface characteristics and transport behavior of E. coli isolates obtained from six different sources. Results of this study showed that a large diversity exists in cell properties and transport behavior for the different E. coli isolates. Because USEPA recommends the use of E. coli as an indicator of fecal contamination in freshwater systems, its fate and transport in the subsurface needs to be better understood. This study shows that generalizations about the transport behavior of E. coli based on results from a single strain of E. coli should be

made with caution. In addition, this large variability suggests that the modeling of E. coli in the environment will require a distribution of bacterial attachment rates, even when modeling E. coli movement from a single fecal source.

Identifying the sources of fecal contamination. Fecal contamination of recreational, drinking and fishing waters is a major global problem. Detecting and ranking the sources of fecal pollution is challenging as common methods used cannot discriminate among the sources. A method for Microbial source tracking (MST) was tested utilizing four genetic markers specific for ruminants to identify the animal source and origin of fecal pollution. Identifying sources of fecal contamination is important because it is the first step in stopping the source. This project investigated two watersheds with different management histories. In the watershed impacted by cattle the four genetic markers specific for cattle were detected in 32 to 65% of the DNA extracted from water and sediment samples. In contrast, at the site not impacted directly by cattle, the genetic markers were detected in only 6% of the water samples. The detection of the genetic markers was correlated to the abundance of the fecal indicator bacteria fecal enterococci. This emerging MST approach removes subjectivity, and offers potential for identifying, tracking, and characterizing fecal sources and reservoirs, provides a tool for remediation and enforcement.

Byproducts: Each year millions of tons of agricultural, municipal and industrial byproducts are generated in the United States. These materials are frequently considered to be wastes and are often disposed in landfills. However, many of these materials have characteristics that make them potentially useful to improve soil properties for enhanced crop production, to prevent movement of contaminants to critical bodies of water, and to lower energy inputs in agricultural systems. Research is being conducted to determine benefits and risks of the materials, to develop and evaluate the effectiveness and economic benefits of byproduct-based management practices and control technologies, to document the environmental benefits of using these materials, and to develop guidelines for specific uses.

Selected Accomplishments

Benefits of flue gas desulfurization (FGD) gypsum. Degraded soils result in reduced crop yields, require higher inputs of fertilizer, water and energy, and pose a greater threat to the environment than high quality soils. Many of the agricultural, industrial and municipal wastes generated each year may be appropriate soil amendments to improve degraded soils. ARS scientists from several locations (West Lafayette, Indiana; Oxford, Mississippi; Tifton, Georgia; and University Park, Pennsylvania) have demonstrated that flue gas desulfurization (FGD) gypsum, generated by removal of sulfur dioxide from the flue gases of coal-fired power plants, can improve soil chemical and physical properties and reduce contaminant movement to surface water. Their research has shown that application of FGD gypsum to soil improves soil structure, resulting in greater infiltration and storage of rainwater. Since water moves into the soil, more is available for subsequent use by crops and less runs off the soil surface, reducing erosion and the movement of sediment, nutrients and trace elements to surface waters. More efficient

infiltration and storage of rainfall is critical to crop production in areas that have recently experienced severe drought, such as the southeastern United States. These results show that a low-cost material like FGD gypsum can allow farmers to increase crop production while improving soil and water quality. The southeastern United States alone has approximately 20 million acres of crop and pasture land that could benefit from application of FGD gypsum.

Impact of Gypsum Applied to Grass Buffer Strips on Reducing Soluble P in Surface Water Runoff. Due to environmental concerns, improved methods to reduce phosphorus loading to surface waters associated with animal production are needed. Studies to evaluate the use of gypsum as a soil amendment to reduce losses of phosphorus from poultry litter in forage based production systems were conducted by ARS scientist in Auburn, AL. The project used rainfall simulation studies to quantify the potential for gypsum to reduce phosphorus in surface water runoff. Gypsum applied to grass buffer strips was effective in reducing soluble P concentrations (32–40%) in surface runoff , while the untreated buffer strip was somewhat effective in reducing soluble P (18%). Results indicated that gypsum could be used in filter strip areas where animal manures are utilized, to reduce environmental degradation due to excess phosphorus.

Increasing biogas production by digesting manure and pulped food wastes. Due to economies of scale, most dairy producers are currently unable to take advantage of anaerobic digestion to treat their animal's waste and produce energy for farm use or sale to others. Simultaneously, there is growing interest in diverting organic wastes from landfills to minimize landfill methane emissions. ARS scientists anaerobically digested mixtures of dairy manure and pulped food to determine how biogas yields were affected by increasing amounts of food wastes. Results showed that reactors containing manure and 5% food waste produced about 20% more biogas than comparable reactors containing only 1% food waste. In addition to increasing biogas yield, on-farm digestion of food wastes with manure may provide opportunities for additional revenue through payments from food waste generators and carbon credits. By taking advantage of nearby wastes that would otherwise be destined for a landfill, smaller dairies might be able to economically treat their manure while developing new sources of revenue, increasing both long-term profitability and resilience to market fluctuations.

Increasing biogas production by digestion of manure switchgrass in high-solids reactors. Although small dairy farms (less than 1000 animals) do not generate enough manure for economic electrical production from biogas, there are opportunities to combine other byproducts with the manure to increase biogas production significantly. ARS scientists in Beltsville, Maryland, anaerobically digested mixtures of three animal manures (swine, poultry, and dairy) and switchgrass to determine which mixture yielded the most biogas. Biogas yields were very low using high-solids reactors containing a 1 to 5 ratio of dry switchgrass mixed with either dairy manure or diluted poultry litter. However, biogas production was relatively high from reactors using a comparable swine manure-switchgrass mixture. In these reactors, approximately 80% of biogas production was attributable to degradation of the switchgrass. Although these experiments are only a

first step in the process, the results suggest that switchgrass could be a useful biomass resource for high-solids digestion.

Old tires are an effective slow release zinc fertilizer. Waste rubber tires are a significant disposal problem in all states, containing about 1.5% zinc, added to rubber to speed vulcanization. Zinc is also a required micronutrient for crop production; some soils, particularly in the western U.S., require the addition of zinc fertilizer. Ground rubber was found to operate as a low grade or slow release zinc fertilizer. In addition, acid extraction of zinc from ground rubber tires produced both a zinc fertilizer for hydroponic production and a lower zinc ground rubber for use as a rooting medium for hydroponic production. No zinc toxicity was observed. Recycling old tires in this way provides a needed inexpensive fertilizer for producers while providing an economically valuable use for the hundreds of millions of waste tires generated each year in the U.S.

Safe use of spent foundry sands as a soil amendment. Each year, up to 10 million tons of spent foundry sands (SFS) are generated in the U.S. which are destined for disposal in landfills due to their assumed toxicity, but tests of SFS as a soil amendment showed that they did not pose a toxicity risk to either plants or earthworms. A comprehensive risk assessment, conducted in cooperation with U.S. EPA, revealed that spent sands from the iron, steel, and aluminum casting industries, were low enough in trace element and toxic contents that they could be safely used as soil amendments or as a component of manufactured soils. The assessment [submitted for peer review by US-EPA] considered multiple exposure routes to humans, livestock, wildlife, and soil organisms. Compared to the disposal of SFS in landfills, use of SFS in both agriculture and horticulture will provide significant environmental benefits as well as savings to numerous industries.

Grasses can remediate soils contaminated with TNT residues. TNT (2,4,6-trinitrotoluene) is a persistent contaminant present in high concentrations on some industrial and military sites. Studies were conducted to evaluate the use of several grasses, tall fescue, perennial ryegrass, and orchard grass, to remove TNT from the soil in a process known as phytoextraction. Results showed that TNT accumulated in the plant shoots during each harvest, period and that the residues were incorporated in plant tissues, thereby eliminating any environmental risk. This work suggests that the overall soil TNT bioremediation goal can be achieved by using multiple grass harvests.

Mixed compost system removes lead and copper from building and parking lot runoff. Some building and parking lot materials will leach lead and copper during rain events which can contaminate nearby waterways. Holding ponds are used to capture this runoff but remediation of the water is still needed in some cases. A study was conducted to test a mixture of composted food waste, yard debris, and steel slag in a filtration system. Laboratory simulations showed that this mixed compost removed lead and copper to levels well below surface water discharge limits. The alkaline steel slag neutralized the acidity generated by reaction of lead and copper with the compost and allowed the compost filter to remain effective much longer than a filter without the steel slag. Thus, this mixed compost, when placed in a large scale filtration system, should

provide an inexpensive, highly effective approach for removing metals in runoff, and protecting nearby waterways.